Analysis of visual demands in a transport category aircraft

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Analysis of Visual Demands in a Transport Category Aircraft

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Introduction

Pilots of transport category aircraft encounter a difficult visual environment, especially if they are presbyopic.

At distance a pilot needs to search for airborne traffic, locate landmarks that define a gate, taxiway, or runway; and align the aircraft for takeoff and landing.

The aircraft's instruments, controls, gages, and annunciator lights situate at an "intermediate" distance of 28-55 inches (73cm-140cm). At this distance the pilot's instrument scan, (in the words of the Federal Aviation Administration instrument "crosscheck, interpretation, and aircraft control,") takes place.[1] Guiding an aircraft solely by reference to instruments requires good acuity, quick and accurate eye movements, good peripheral vision; and well developed visual-motor and visual-perceptual abilities. The instrument scan differs from reading in several aspects. Reading usually has a relatively fixed accommodative and vergence demand. The saccades move in a left-right direction, with a return sweep to the left. Most novels, magazines, and newspapers require short saccades (velocity 100 degrees/second), and short return sweeps. In a large jet, information is assimilated from three-dimensions, therefore accommodative and vergence demands constantly change. Saccades travel up, down, left, right, and obliquely. They travel farther distances, thus gaining greater velocity (around 300 degrees/second).[2,3,4] This places a premium on peripheral awareness. Figure 1 shows the layout of a McDonnell Douglas DC-10 instrument panel.

At the most fundamental level, the scan involves setting power referencing the power gages, and establishing an attitude (pitch and/or bank) referencing the Attitude Indicator. The Attitude Indicator, or "artificial horizon," gives a direct indication of pitch and bank. The pilot crosschecks the Airspeed Indicator, Altimeter, Vertical Speed Indicator, Turn Coordinator and Directional Gyro (Horizontal Situation Indicator) to determine aircraft performance. Various scanning techniques exist. However, the most used technique involves monitoring the Attitude Indicator, with quick saccades to the other instruments. In more sophisticated aircraft, Weather Radar, the Traffic Collision Avoidance System, GPS, the Flight Director System, the Autothrottle System, and the Autopilot System must be incorporated into the scan.

Near activities at 16-24 inches (40cm-61cm) include reading checklists, manuals, and navigation charts. Aeronautical charts are densely packed with information. Figure 2 shows an instrument approach plate from Jeppesen Sanderson Company, and one by the National Aeronautical Charting Office (Part of the United States Department of Transportation, Federal Aviation Administration).

The pilot encounters the full gamut of environmental conditions that compound piloting tasks: from haze, smoke, and fog, to the extreme brightness of flying into the sun at 35,000 feet, to flying over water at night in rain.

FAA Part 67

The Federal Aviation Administration (FAA) recognizing the importance of the demands at the intermediate distance, and the abilities of the presbyope, using recommendations from the American Medical Association, instituted new Federal Aviation Regulations Part 67 vision standards for the First Class Medical Certificate, effective September 16, 1996. Box 1 summarizes the vision standards for the First Class Medical. Note that for pilots over the age of 50 there is a 20/40 acuity standard, with or without correction, at a distance of thirty two (32) inches (81cm. An accommodative demand of 1.23D).[5,6,7]

Yolton, Asmus, and Holnagel concluded, "most optometrists do not have a thorough understanding of the Federal Aviation Administration's regulations governing pilots…"[8]

Depending on accommodation and depth of focus, the optometrist can recommend several options in spectacles and/or contact lens. The Progressive Addition Lens would theoretically be a lens of choice for the presbyopic pilot. However, these lenses have not caught on hugely because they have some drawbacks that pilots working in large cockpits do not like. See figure—for a demonstration and discussion why. The cockpit's layout mandates good peripheral vision. Some pilots feel PALs distort the periphery too much. In fact the United States Air Force will not allow their pilots to wear Progressive Addition Lenses. A survey of airline pilots over the age of 40 showed only 25% wore progressives. See Box 2.

They survey shows that only 10% wear contact lens. Several pilots from the survey commented that their eyes became very irritated wearing contacts in the aircraft. One recommendation is to use the new silicon hydrogel soft contact lens coming to market.

Yolton et al. discuss the necessity of the optometrist working with pilots to calculate the appropriate add power(s) and determine the correct seg(s) location. To accomplish this the optometrist must understand the working distances, tasks, and peripheral requirements involved.

It should be made clear to aviation and vision care professionals that the Federal Aviation Administration prohibits several modalities. They are "monovision" spectacles and contacts, and pupil size-dependent multifocal contacts. The FAA feels these reduce binocular depth perception.[9,10]

Certain types of sunglasses are also contraindicated while flying. These are polarized sunglasses, and certain types of opaque and translucent colored contact lenses. Green tints in sunglasses are strongly discouraged. Neutral gray makes for the best tint.[6,11]

Optimizing visual performance

Optimizing instrument displays and lighting can enhance visual performance. Likewise, well designed aeronautical charts combined with optimum illumination assists the pilot, especially with so much crucial information packed together.

From the 1940's through the 1970's, a multitude of studies were conducted to find the optimum width to height, w/h, stroke-width to height, sw/h, and spacing to height, s/h, ratios for white on black (positive contrast) and black on white (negative contrast) characters of a given height. Some were field studies, and some involved cockpit instrumentation. One study evaluated the legibility of British license plates. Another studied the legibility of highway destination signs in the United States. These studies gave a wide range of conclusions, some directly contradicting others.

Zwahlen, Sunkara, and Schnell took the various studies, and using second-order polynomial, least squares fit, tried to come up with the optimum ratio for each of the six parameters. Given the wide variety of methodologies and data completeness used in the various studies, the authors had difficulty coming up with enough data points for their statistical analysis. In some instances they had to assume certain criterion, and extrapolate data. In the case of s/h, they simply gave a range of the data. See Table 1. Zwahlen, Wentz,

and Schnell related these findings to the legibility of a general aviation altimeter. They concluded certain features of the altimeter design should be modified. The authors are big believers in the "size matters" philosophy of character legibility.[12]
Unfortunately, sometimes space is limited.

Vision care providers and researchers have standards for the optimum dimensions for character legibility. Most Snellen "optotypes" are five units high, and four or five units wide (w/h=4/5=0.80 or 5/5=1.00). The stroke-width is one unit (sw/h=1/5=0.20).

The "Landolt Ring" or "Landolt C," is five units by five units (w/h=1.00). The stroke-width is one unit (sw/h=0.20), and the gap in the "C" is one unit by one unit. The NAS/NRC Committee on Vision, and the Concilium Ophthalmologiium Universale have recommended that it be used as the reference against which the legibility of other optotypes should be calibrated.[13]

The vision community does not have a consensus for the spacing to height, s/h, ratio. Borish's Clinical Refraction lists the disagreements between the various organizations.[13] However, consider these studies. "Flom et al. found that contour interaction started to effect resolution of the gap in the "C" when bar spacing equaled letter size. The maximum affect occurred when spacing was 4/10 of letter size."[14] Other studies showed that when spacing between letters varied from 0.50 to 3.0 times letter height, a two-fold change in spacing altered the acuity approximately 0.05 log units.[13] As an example, 20/50 acuity improved to 20/45 when s was doubled. Psychometric acuity charts use interletter spacing equal to letter size. Davidson and Eskridge's psychometric charts use spacing of one half-letter size.[14]

Two phenomena influence the ability to resolve fine detail when symbols are tightly packed and near threshold. The first is "contour interaction." The physical nearness of the lines and contours of the closely adjacent letter impinges on a person's ability to distinguish fine detail on the letter being viewed. The second factor is called "crowding effect." Discriminating fine detail of threshold letters, or numbers, becomes more difficult because finer eye movement control and fixation is needed.

Lighting

Lighting inside the cockpit consists of map and reading lights, floodlights to illuminate specific areas, and instrument and display backdrop lighting. These lights have adjustable rheostats. Overhead "dome" and "thunderstorm" lights provide non-adjustable general lighting.

Lighting has an effect on the ability to discriminate a character. It takes 2-3 candelas/m^2 of luminance to see a 20/20 letter. With one candela/m^2 of luminance the best acuity possible would be 20/25.[11,24]

As a reference, optimal chart luminance for testing vision is considered to be 160 cd/m^2, with a range of 80-320 acceptable. The optimum luminance for seeing is 1400 cd/m^2, and the luminance off a white page in good reading light is 100 cd/m^2.[11,16] Scotopic vision starts below 0.01 cd/m^2. Photopic vision begins at about 10 cd/m^2. No standard exists for mesopic vision. It, depending on who you trust, ranges from 0.01-10 cd/m^2, to 0.01-3 cd/m^2, to 0.01-1 cd/m^2.[19,17,18]

Light affects the ability to distinguish colors on charts. As luminance falls below 1cd/m^2, Wentz et al. use 3 cd/m^2, colors start to fade, beginning with red. This puts the pilot in a bind at night. He/She wants to keep the lights dim to adapt, but too dim a light compromises color vision. This is an important point because some publishers are starting to add color to their approach charts.

Pitts et al. state that lighting continues to be an "Achilles Heel" to optimum vision performance.[11]

Blackwell studied luminance versus legibility for subjects of various ages. Wentz, Zwahlen, et al. applied these studies toward the legibility of the display of a general aviation altimeter, and found it was not optimal. Their recommendations were as follows: one, increase luminance levels to help elder pilots; and two, cockpit displays and luminance levels of other aircraft should be surveyed to see if there is a need for overall improvement.[12]

Based on Wentz, Zwahlen, and Schnell's recommendations, Pitts et al. suggestion that optometrists need to educate other professions what constitutes good lighting, and Yolton et al. survey that showed 60% of optometrists have not familiarized themselves with visual demands of the cockpit, we examined various instrument displays and luminance levels in a McDonnell Douglas DC-10. An evaluation of a Jeppesen Sanderson Instrument Approach Chart was also conducted.

Methods

The McDonnell Douglas DC-10 used for this project was as equipped and maintained by Hawaiian Airlines and American Airlines. Two male subjects were tested: one 6'3" in the Captain's seat, and the other 5'11" in the First Officer's seat.

Both seats were adjusted for height, and lengthwise to replicate as best as feasible seat placement relative to instrument panel for the typical pilot, fully realizing that each pilot has his/her own technique for chair placement.

A tape measure was used to measure the distance from the eyes to various gages, lights, displays and instruments. Vertical and horizontal angles were taken to various displays, controls, lights, instruments, and gages using a Vision Disk from Hubbard Scientific, purchased through Bernell.

Measurements were taken in the cockpit, at the gate, on the actual instruments using a vernier caliper and illuminated magnifying glass. In some instances, a transparent ruler was used. Acuity demand was calculated using the average distance of the two subjects for the various displays. See Table 2. Note that the "near" distance for reading an aeronautical chart is in the vicinity of 20 inches, and not 16. This could make a difference when determining an add power.

To examine light levels replicating night flying, a black felt curtain blocked outside ambient light. Luminance levels were then taken under various lighting setups at different displays, and instruments using a Photometer. The idea was to recreate luminance levels of cockpit lighting during various phases of night flight. We concentrated on display luminance at the GPS, Vertical Gyro (Attitude Indicator), and Flight Director System. Emphasis was also placed on luminance levels at the chart holder on the yoke. See Table 6.

The Instrument Approach Plate, Lihue, Hawaii ILS Rwy 35, from Jeppesen Sanderson was analyzed with a vernier caliper and illuminated magnifying glass, 5x/20D/140 from Eschenbach. Some measurements were taken with a plastic transparent ruler. Acuity for the Jeppesen charts was based on a working distance of 21 inches (53.35cm), for an accommodative demand of 1.90D. See Table 4.

Results/Discussion

Comparing Tables 1 and 7 to Table 3 shows mixed results. All of our measurements on the DC-10 showed character size larger than 20/40 acuity demand. This keeps every letter and number above the standard for the First Class Medical at intermediate distance. No sense having a pilot seeing 20/40 and passing the physical, all the while having displays with 20/30 demand. And to quasi paraphrase Wentz, Zwahlen et al., "bigger is better." Most measurements fall into the 20/80-20/100 range. The smallest size, at 20/50 acuity, are the ball of the Attitude Indicator, and the "5" and "1" on the Vertical Speed Indicator.

Only the ball of the attitude indicator shows a w/h ratio of 1.00, and only a handful of characters have a w/h of 0.80 or greater. The majority falls into the 0.65-0.75 ratio. Those dimensions do not quite meet optimum standards. See Table 3.

Some numbers, such as the N1 gage, for instance, exceed the 0.20 ratio for sw/h. Some meet the 0.20 ratio, and the majority fall into the 0.15-0.20 range. This does not meet the vision researcher's criterion but fall within Zwahlen's et al. criterion.

The s/h ratios, when calculated, fell into the 0.20-0.30 range. This does not meet vision research standards. But the 0.27 (white on black "150" on the Airspeed Indicator) just about meets Zwahlen's et al. calculated optimum.

Increasing w/h, sw/h, and s/h ratios on the DC-10's displays would enhance legibility and may contribute to a more efficient scan.

We can compare the ratios of Tables 1 and 7 to Table 4. We used Jeppesen's ILS Rwy 35 Instrument Approach Chart into Lihue, Hawaii for our analysis. See Figure 2. The "briefing strip" on the approach plate summarizes the most pertinent information a pilot needs to know while commencing an instrument approach. The numbers 110.9 and 2119, measure out to approximately 20/60. The 0.67 ratio for w/h falls short of the minimum goal of 0.80 (and the preferred goal of 1.00). The sw/h ratios come very close to 0.20. The s/h ratio varies depending on the combinations of adjacent numbers. Some combinations meet Zwahlen's et al. optimum, and some even meet Davidson and Eskridge's (spacing equal half letter height). The s/h ratios far exceed the s/h ratio found in Time and Newsweek. See Table 5. These calculations from Time and Newsweek were included in this report for comparison to the "Jep" chart.

The letters of the briefing strip, "ILIH" and "Akule" are slightly smaller in size, 20/40, and keep about the same w/h and sw/h dimensions. They have smaller s/h ratios than their counterpart numbers.

The "plan view" of the approach chart has black on gray contrast. This lower contrast comes into play when it will be shown later that this part of the chart can have significantly lower luminance levels-therefore making it hard to read, especially for the elder pilot. The characters in the bold box have demand size of 20/55, w/h ratio of 0.70, and an sw/h ratio of 0.20. The s/h in the whole plan view range from 0.09 to 0.36, again falling short of optimum criterion, but better than the magazines used for comparison.

Toward the bottom of the chart, at the conversion table and missed approach point data, all the demensions decrease. Acuity demand approaches the 20/30-20/35 range. The character size exceeds the vision standard for that distance, 20/40. You now theoretically have the situation where the pilot is "legal" to fly but cannot read critical information about the approach when placed at its normal position.

That section of the approach chart needs to be improved to meet the 20/40 acuity criterion. Likewise, increasing the w/h and s/h ratios (and it seems there is the space to do it) of the characters for the whole chart would increase legibility. This is important because in the next section it will be shown that luminance from the charts falls way below optimum.

Remember, optometrist use 160 cd/m^2 (with a range of 80-320) for their charts. Several sources say 1400 cd/m^2 makes for optimum vision. Some sources have 10 cd/m^2 in the mesopic range. As shown in Table 6, 6 cd/m^2 may be sufficient for 20/20 vision and color discrimination, but it is far from optimum. One cd/m^2 has the potential to makes things difficult for the elder pilot.

Luminance levels taken at different sections of the chart shows that just a short distance from the light source, luminance falls to 1 cd/m^2. See Table 6. This compromises acuity and color discrimination on the Lihue, Hawaii ILS Rwy 35 approach chart in low contrast sections, like the "plan view." Earlier we stated that Jeppesen Sanderson has added color to their approach charts. Many pilots have complained about difficulty reading charts in low illumination. One suggestion is to install an apparatus on the yoke that holds charts and checklists, and distributes optimum, uniform lighting to all sections. The "Glo-Page," using an internally lit prismatic panel, from U.S. Acrylic is an example.

Conclusion

This project attempted to accomplish several goals. One was to explain the visual requirements, tasks, and challenges placed on an airline pilot, especially a presbyope. It was hoped this would give optometrists the background to make informed recommendations concerning corrective lenses.

While outlining visual demands, we analyzed the design of a Jeppesen Sanderson Instrument Approach Chart to see if it maximized character legibility. We concluded certain sections needed to be improved to meet acuity requirements. Improving w/h, and s/h ratios on the whole, which should be possible, would also be very beneficial.

As suggested by Wentz et al., we analyzed the display legibility and luminance levels in a McDonnell Douglas DC-10. It was found that display legibility was adequate, and could be improved by enhancing w/h, sw/h, and s/h ratios.

Although there is sufficient light to get the job done, luminance levels in a McDonnell Douglas DC-10 fall well short of recommendations. Pitts et al. remind optometrists they have a leading role in educating other professions what "constitutes inadequate lighting and how it can be remedied."[11]

This project may be a case in point. One immediate suggestion would be to install a device like the "Glo-Page," from U.S. Acrylic, on the yoke of commercial aircraft to hold aeronautical charts.

Box 1

Vision Standards First Class Medical Certificate.

Distant Vision-Distant visual acuity of 20/20 or better in each eye separately, with or without corrective lenses.

*Intermediate Vision-50 years or older, vision of 20/40 or better, Snellen equivalent, at 32 inches in each eye separately, with or without correction.

Near Vision-Near vision of 20/40 or better, Snellen equivalent, at 16 inches in each eye separately, with or without corrective lenses.

Hyperphoria-Maximum of 1 diopter.

Phoria-Maximum of 6 diopters esophoria or exophoria.

Color-Ability to perceive those colors necessary for the safe performance of airmen duties.

Field of Vision-Normal fields of vision.

Pathology No acute of chronic pathological condition of either eye or adnexa that interferes with the proper function of the eye, that may reasonably be expected to be aggravated by flying.

Box 2.

Survey of airline pilots over age 40.
Percentage of types of correction worn in the cockpit.

Type	Percentage
None	13
Spectacles*	
Single Vision (including "cheaters" bought at store)	21
Bifocals	30
Trifocals	3
Progressives	23
Contact Lens	10

*Two responded they use single vision during day and bifocals at night.

Table 1. Zwahlen, Sunkara, Schnell et al. Optimum Legibility Parameters, w/h, sw/h, and s/h. From **Human Factor Consideration of Aircraft Display**, Society of Automotive Engineers, 1998

Parameter	White on Black Contrast Positive Contrast	Black on White Contrast Negative Contrast
W/H Ratio Width to Height	0.83	0.89
S/H Ratio Spacing to Height	0.28	0.43
SW/H Ratio Stroke-Width to Height	Ranges given by various Studies[12] 0.17 0.125-0.17 0.20	Ranges given by various Studies[12] 0.125 0.1 0.125-0.20

Table 2a. Subject 1. 6'3" in Captain's seat

Instrument/Display/Control	Inches	Centimeters (cm)	Horizontal degrees	Vertical degrees
Approach plate on **yoke**	21.5	54.61	0	
Top				Down 35
Bottom				Down 45
Attitude Indicator "Artificial Horizon" "Vertical Gyro" "ADI"	33.5	85	0	Down 15
Directional Gyro "Horizontal Situation Indicator."				
Top-Heading bug	34	87	0	Down 20
Middle	34.5	88	0	Down 25
Weather Radar/TCAS	34	86	40	Down 35
GPS	34.5	87	20	Down 45
Flight Director/Auto Pilot Panel				
Capt. Nav.	25.5	64	25	Down 10
"Alt Hold"	30	76	40	10 Down
"HDG"	29	73	35	10 Down
"ATS"	28	71	32	10 Down
#2 N1 Gage	39	99	25	15 Down
#2 Fuel Flow Gage	41	104	25	25 Down
High Frequency Radio #2	29.5	75	35	Up 30
Antiskid Switch	18.5	47		Up 20
Annunciator Panel- Middle	27	69	25	Up 15
Captains Airspeed Indicator	34	86	10	Down 15
To F/O's Airspeed Indicator	49	125	45	

Table 2b. **Subject #2. 5'11" in First Officer's Seat**

Instrument Display	Inches	Centimeters	Horizontal Degrees	Vertical Degrees
Approach Plate On Yoke	20	51	0	Top: Down 45 Bottom: Down 55
Attitude Indicator	32.5	82	0	Down 20
Weather Radar/ TCAS	31	79	40	Down 45
GPS	33	84	15	Down 45
Flight Director/ Auto Pilot				
F/O's Nav	23	58	15	Down 12
Alt Hold	26	66	20	Down 12
"HDG"	27	66	25	Down 12
"ATS"	29	73	50	Down 12
#2N1 Gage	36	90	40	Down 20
#2 Fuel Flow	36.5	93	40	Down 35
Directional Gyro "Horizontal Situation Indicator"	33	84	0	Top Heading "Bug" Down 30 Center: Down 32
Max Speed Warning	13.5	34	8	Up 20
"Cont A"	18.5	47	30	Up 30
#1 High Frequency Radio	24	61	50	Up 30
Middle Annunciator	21	53	40	Up 20
Flaps	33	83	20	Down 45

Table 3. Calculations of Acuity, w/h, sw/h, and s/h on McDonnell Douglas DC-10 (See Figure 1).

Attitude Indicator

	Contrast	Acuity	W/H	Sw/h
"5"	Orange on Light Blue/Black	20/65	0.67	0.18
Ball of Simulated Aircraft	Various	20/50	1.00	

Airspeed Indicator

	Contrast	Acuity	W/H	SW/H	S/H
.150	White on Black-Positive	20/105	0.80	0.15	0.27
"80"	White on Black-Positive	20/80	0.80	0.20	

Altimeter

	Contrast	Acuity	W/H	SW/H	S/H
"O".000	Positive	20/145	0.64	0.17	
O.000	Positive	20/110	0.64	0.22	0.14
"0"	Positive	20/95	0.65	0.16	
"5"	Positive	20/80	0.69	0.17	
"30.02"(29.92)	Positive	20/65	0.63		

Directional Gyro/Horizontal Situation Indicator

	Contrast	Acuity	W/H	SW/H	S/H
000.0	Positive	20/95	0.80	0.20	0.21
"0" and "27"	Positive	20/95	0.80	0.18	

Table 3. Continued.

Radio Altimeter

	Contrast	Acuity	W/H	SW/H
$\boxed{100}$	Positive	20/70	0.67	
"0"	Positive	20/80	0.60	0.16
"100"	Positive	20/80	0.60	

Vertical Speed Indicator

	Contrast	Acuity	W/H	SW/H
".5"	Positive	20/50	0.73	0.20
"1"	Positive	20/50		0.20
"0"	Positive	20/80	0.85	0.16

N1 Gage

	Contrast	Acuity	W/H	SW/H
"60"	Positive	20/57	0.625	0.25
$\boxed{00.0}$	Positive	20/85	0.67	0.25

GPS

Contrast	Acuity	W/H
Light on Dark	20/65	0.625

Flight Director-Auto Pilot-Auto Throttles Systems

Contrast	Acuity	W/H	SW/H
Positive	20/195	~0.20	0.50

Annunciator Lights

Contrast	Acuity	W/H
Positive	20/90	0.50

Table 3. Continued.

Instrument	Needle Length. Centimeters. cm.	Needle Width. mm.	Tic Width. mm.	Tic Length. mm.	Distance Between Marks mm.
Attitude Indicator			0.7		4.1
Airspeed Needle	3.32	Thickest 3.0 Thinnest 1.0			
Major Tic Mark-Airspeed			0.9	8.0	
Minor tic-Airspeed			0.7	3.2	1.7
Altimeter Needle	2.8	Thickest 2.8 Thinnest 1.0			
Major Tic Altimeter			0.9	6.0	
Minor Tic Altimeter			0.65	2.5	~3.3
Directional Gyro Needle	7.2	Thickest 1.7 Thinnest 0.8			
Major Tic DG			0.95		
Minor Tic DG			0.8		~3.3
Radio Altimeter Major Tic			0.7	10.0	
Radio Altimeter Minor Tic			0.5	5.5	3.1
Vertical Speed Needle	2.6	Thickest 3.1 Thinnest 1.2			
VSI Major Tic			1.1	4.2	
VSI Minor Tic			0.9	2.8	1.0-2.3
N1 Gage Needle	2	Thickest 3.0 Thinnest 1.0			
N1 Tic Marks			1.0		~1.9

Table 4. Measurements of a Jeppesen Sanderson Approach Chart, Lihue, Hawaii, ILS Rwy 35

"Briefing Strip"-Numbers

	Contrast	Acuity	W/H	SW/H	S/H
"110.9"	Black on White-Negative.	20/62	0.65	0.17	0.31-0.60
"2119"	Black on White-Negative.	20/65	0.64	0.18	0.34-0.60

"Briefing Strip"-Letters

	Contrast	Acuity	W/H	SW/H	S/W
"ILIH"	Negative	20/40	0.625	0.16	0.22-0.28
"Akule"	Negative	20/40	~0.70	0.20	0.13-0.33 Typical=0.2

Plan View

	Contrast	Acuity	W/H	SW/H	S/H
"349" "110.9" "ILIH"	Black on Gray*	20/55	0.70	0.20	0.13-0.36 Typical Ave. 0.29
.. ._..	Black on Gray*	20/15	1.00		0.55
"Akule"	Black on Gray*	20/55	0.54-0.77	0.20	.09-0.16 Ave. 0.16

Profile View

	Contrast	Acuity	W/H	SW/H	S/H
"7.2"	Black on White-Negative	20/40	0.63	0.14	
"2119"	Negative	20/45	0.67	0.22	0.40
"GS 288"	Negative	20/45	0.67	0.22	0.22

Conversion Table and Missed Approach

	Contrast	Acuity	W/H	SW/H	S/H
"Gnd speed-Kts."	Negative	20/30**	0.60	0.15	0.15-0.38 Ave.-0.23
"Akule to MAP"	Negative	20/35**	0.60	0.18	~0.18

Table 5. Measurements of a typical paragraph, using small letters, for Time and Newsweek for Comparison.

Time

Contrast	Acuity	W/H	SW/H	S/H
Negative Black on White	~20/50	0.80	0.133	~0.13

Newsweek

Contrast	Acuity	W/H	SW/H	S/H
Negative Black on White	~20/50	0.90	0.133	0.13

Table 6. Luminance levels in the McDonnell Douglas DC-10 Cockpit Using Photometer.

Lighting-Instrument backdrop lighting-range of levels from selected displays.

	Luminance cd/m^2
"SPD" Command on Flight Director/Auto Pilot Controls	1.0
Attitude Indicator	<.5 - 1.5 - 3.3 - 4.5 Ave. ~1.5
Yoke	<.5

GPS

Black

Tail NO

1.0 cd/m^2 1 $_{2.0\ cd/m2}$ 2 $_{2.0\ cd/m2}$ 5

Black

Approach Plate on Yoke-yoke light at full intensity and minimal backdrop lighting.
Luminance levels at various sections of the chart (See Figure 2).

	Luminance cd/m^2
"Akule" Briefing Strip	5.6
Left End of Briefing Strip	1.0
"110.9"	2.7
"349"	4.2
"2119"	6.0
"296"	5.3
"96"	2.0
Right End of Briefing Strip	0.8
"Akule"-Plan View	1.1

General Lighting
Measured at the yoke.

	Luminance cd/m^2
"Thunderstorm Light"	5.4
"Dome Light"	4.5

Table 7. Standards Used by Vision Researchers for legibility.

W/H Ratio	SW/H Ratio
0.80 Minimum 1.00 Recommended by NAS/NRC and COU	0.20

S/H Ratio Recommendations/Standards Used by Researchers or Organizations.

Researcher/Organization	S/H Ratio
NRC Working Group 39*	1-2 letter heights. Varies.
Concilium Ophthalmologicum Universale*	1-2 letter widths. Uniform.
International Standards Organization*	1.5 letter height 20/150-20/60. 2 letter height 20/50-20/20.
Davidson and Eskridge**	0.5 letter size
Flom**	Spacing less than 1.00 starts to influence legibility. Max influence at 0.4 height.

*From Borish's Clinical Refraction, 1998. Page 200.

**From Griffith.

Figure 1. Distance from center of Attitude Indicator to other Instruments.

	Distance-Centimeters
Edge of Airspeed Indicator	8
Middle of Airspeed Indicator	12
Edge of Altimeter	12.5
Middle of Altimeter	16
"Bug" of Directional Gyro "Horizontal Situation Indicator"	9
Middle Directional Gyro	13.5
Edge Vertical Speed Indicator	12
Middle VSI	15
#2 N1 Gage	55
Radio Altimeter	9

Figure 1b

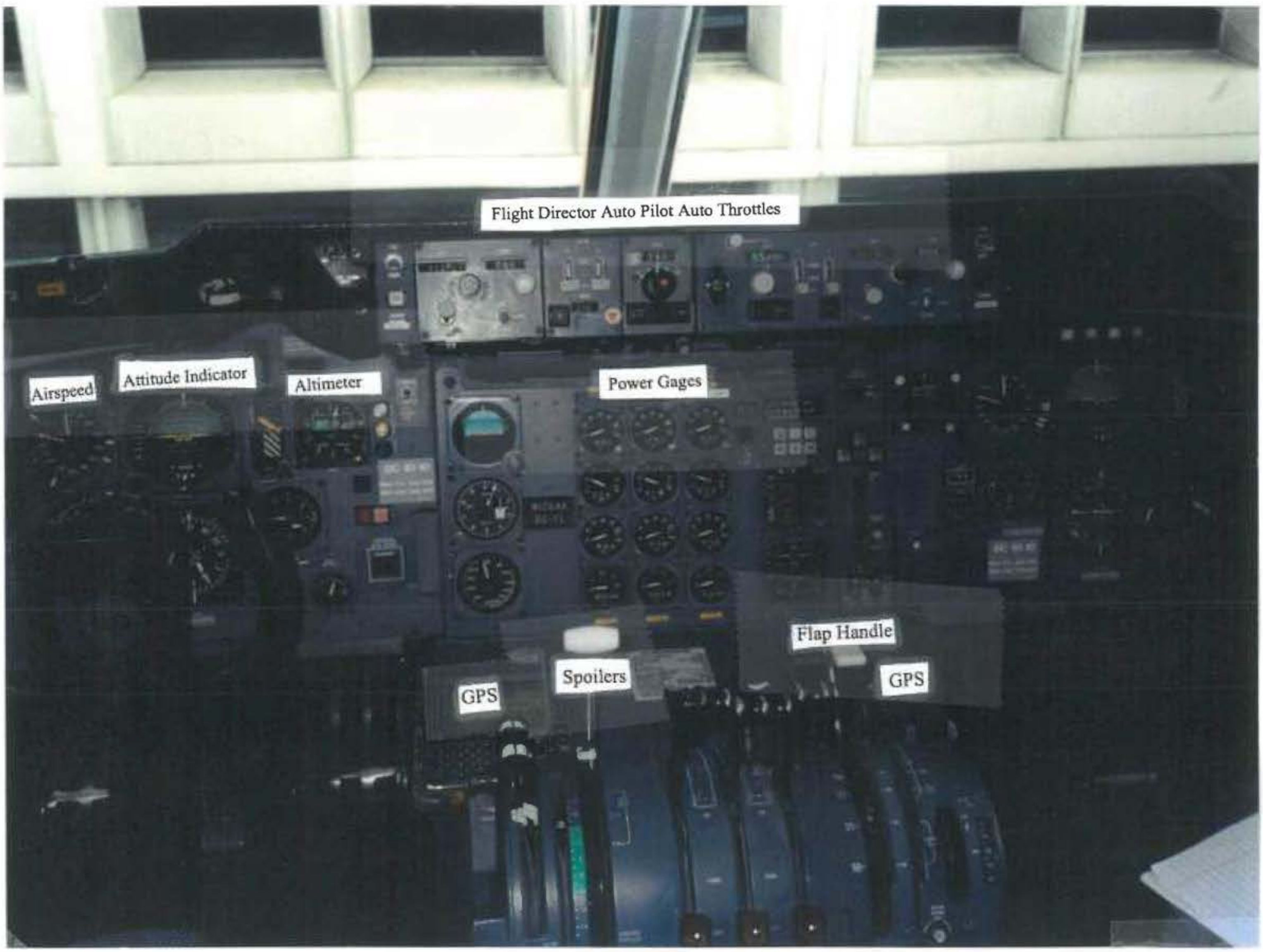

Flight Director Auto Pilot Auto Throttles
Airspeed
Attitude Indicator
Altimeter
Power Gages
Flap Handle
GPS
Spoilers
GPS

Figure 2a

Jeppesen

PHLI
LIHUE

JEPPESEN
24 SEP 99 (11-1) Eff 7 Oct

LIHUE, HAWAII
ILS Rwy 35

7(6)
2000

5.4
1500

4
1000

3
700

BRIEFING STRIP™

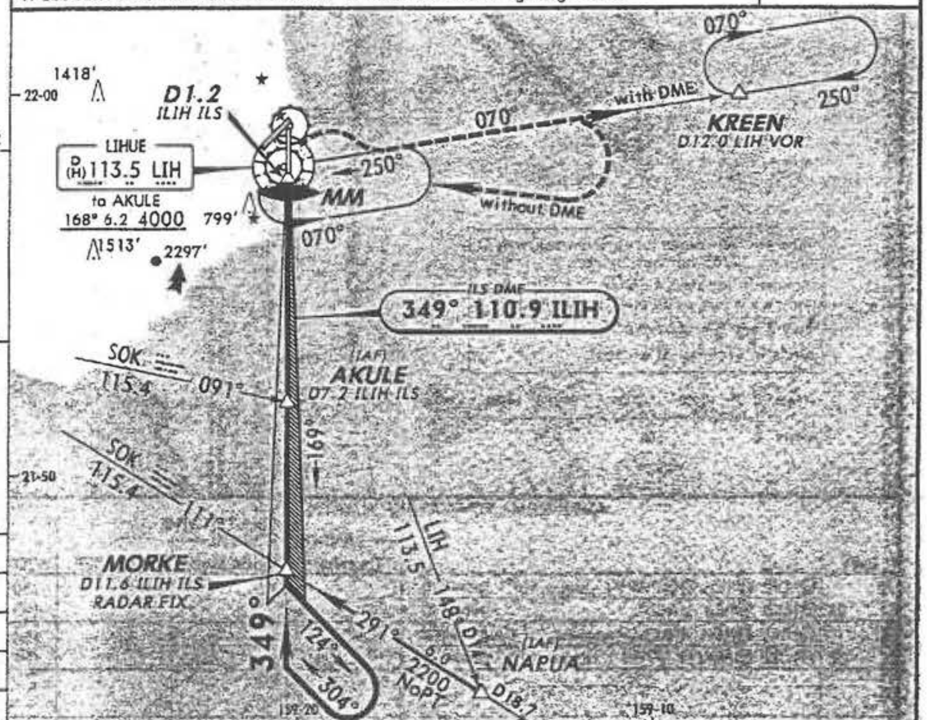
ATIS	HONOLULU Center (R)	*LIHUE Tower	*Ground	*Helicopter
127.2	126.5	CTAF 118.9	121.9	128.4

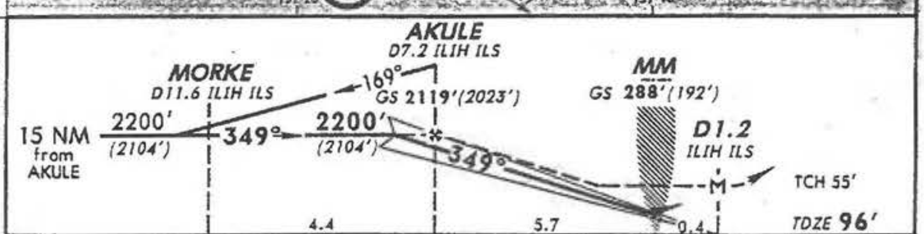
LOC ILIH	Final Apch Crs	GS AKULE	ILS DA(H)	Apt Elev 153'
110.9	349°	2119'(2023')	296'(200')	TDZE 96'

MISSED APCH: Climb to 600' then climbing RIGHT turn to 3000' outbound via LIH VOR R-070. DME aircraft continue to KREEN D12.0 LIH VOR and hold. Non-DME aircraft continue climb to 4000' then RIGHT turn direct LIH VOR and hold.

Alt Set: INCHES Trans level: FL 180 Trans alt: 18000' (17904')
1. Use ILIH DME when on LOC course. 2. Pilot controlled lighting 118.9.

6300' 195° 055° 3600'
MSA LIH VOR





Gnd speed-Kts		70	90	100	120	140	160
GS	3.00°	379	487	541	649	757	865
MAP at D1.2 ILIH ILS or AKULE to MAP	6.1	5:14	4:04	3:40	3:03	2:37	2:17

MALSR
PAPI
600'
3000' RT
LIH via 113.5 R-070

STRAIGHT-IN LANDING RWY 35

CIRCLE-TO-LAND
Not Authorized Northwest of Rwy 3-21

	ILS DA(H) 296'(200') FULL	ILS RAIL or ALS out	LOC (GS out) MDA(H) 420'(324')	LOC RAIL out	LOC ALS out	Max Kts	Acft are Required to Maneuver East of LIH VOR MDA(H)	Rwy 3 MDA(H)
A	1/2	3/4	1/2	3/4	1	90	540'(387')-1	540'(387')-1
B						120	600'(447')-1	1100'(947')-1 1/2
C						140	600'(447')-1 1/2	1100'(947')-3
D			3/4	1		165	700'(547')-2	1540'(1387')-3

AMENDS

Figure 2b

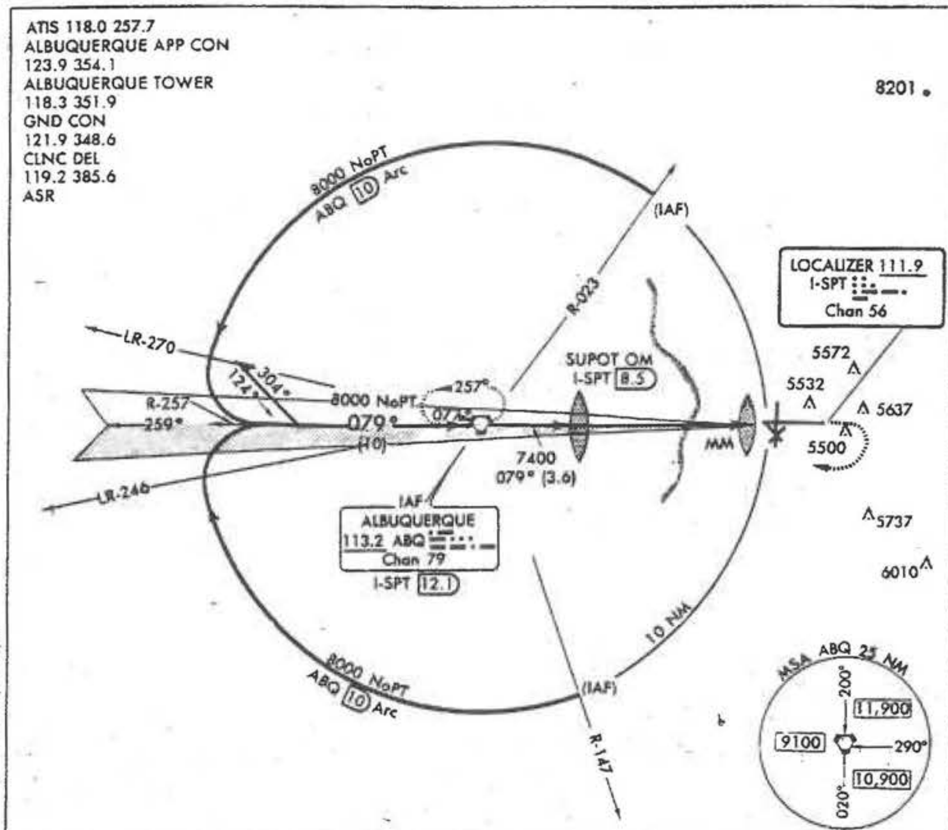
National Aeronautic Charting Office

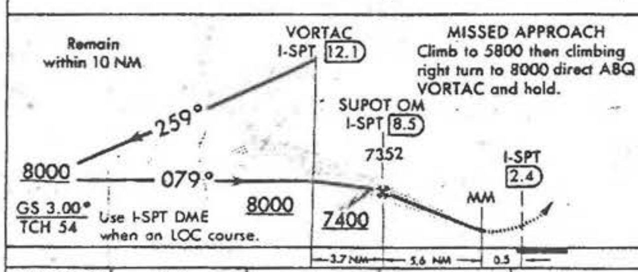
Amdt 5B 01221

ILS RWY 8

AL-12 (FAA)

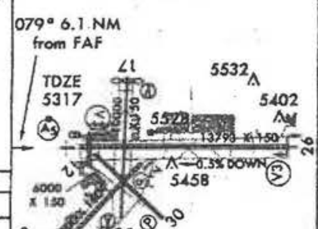
ALBUQUERQUE INTL SUNPORT (ABQ)
ALBUQUERQUE, NEW MEXICO





ELEV 5355

Rwy 8 ldg 12,793'
Rwy 17 ldg 9110'
Rwy 35 ldg 9110'



CATEGORY	A	B	C	D
S-ILS 8	5517/24 200 (200-½)			
S-LOC 8	5640/24 323 (300-½)			5640/40 323 (300-¾)
CIRCLING	5840-1 485 (500-1)		5900-1½ 545 (600-1½)	5920-2 565 (600-2)

For inoperative MALSR, increase Cat D S-LOC 8 visibility to RVR 5000.

REIL Rwys 17, 26, 30 and 35
HIRL Rwys 3-21 and 8-26
MIRL Rwys 12-30 and 17-35
TDZ/CL Rwys 3 and 8

FAF to MAP 6.1 NM					
Knots	60	90	120	150	180
Min:Sec	6:06	4:04	3:03	2:26	2:02

CN, 9 AUG 2001

CN, 9 AUG 2001

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Biography

Clay Searl graduated from UCLA in 1983 with a degree in Economics. Always interested in vision he entered Pacific University's College of Optometry in 1996. After taking two years off to fly with his employer, Hawaiian Airlines, he returned to Pacific to finish his optometry studies. Clay spent 16 weeks at the United States Air Force Academy Hospital as one of his clinical rotations. There, he was able to use his background in sports and aviation to assist the coaches who run the Academy's Human Performance Lab; of which Sports Vision is an integral part. After completing his degree he will return to Honolulu, Hawaii, his hometown, to resume his career flying with Hawaiian Airlines, and use his optometric skills to help pilots, athletes, students, and anyone else interested in maximizing their visual performance.